Power Trip
Occupational Health Issues in the Power Generation Industry

By Connie L. Muncy

Fossil fuel power generation operations harbor many various occupational health hazards. These chemical, biological and physical hazards range from the routine to the rare. This article discusses the importance of anticipating and characterizing all occupational health hazards, and illustrates a sampling of these hazards. In reviewing these examples, remember two key points: 1) hazards, exposures and controls will vary significantly from one site to another; and 2) exposures may be adequately managed through appropriate controls.

Anticipating Workplace Health Hazards in the Power Industry

The risk faced by power industry employees is a function of the hazards present and the exposure level to those hazards. An organized, systematic method of exposure and risk assessment is key to controlling these risks through a successful, effective occupational health and industrial hygiene program. The use of this systematic method, known as qualitative exposure assessment (QEA), to characterize workplace exposures to chemical, physical and biological agents is the solid foundation of this process (Figure 1, p. 50).

Initial qualitative exposure assessments typically involve a site visit by an industrial hygienist who will interview personnel and examine work areas for hazards, controls, work activities and chemicals. This initial assessment represents a snapshot in time; it is performed within a limited time frame and depends heavily on information provided by employees, limited observations, and the assessor's skills and experience. Thus, this initial assessment tends to be somewhat limited in its comprehensiveness.

Complicating matters, after completion of the initial assessment, operations, materials, equipment and conditions are ever-evolving and highly subject to change. To ensure a sustainable hazard control program, a continuous improvement cycle must be woven into the QEA process.

Key components of this process are effective hazard reporting systems, scheduled periodic reassessment of hazards, and implementation of management of change processes. Additional strategies are also needed to capture impactful but nonroutine/less obvious occupational health hazards that might otherwise be missed.

Hygienists may find it beneficial to:

- Establish a genuine, trusting relationship with plant staff.
- Train staff effectively to identify possible occupational health hazards and act as the hygienist's eyes and ears in the field.
- Mentor site monitors when a continuous on-site presence is not possible.
- Be communicative and responsive to requests for assistance about perceived health hazards.
- Always act ethically.
- Keep commitments.
- Maintain a visible on-site presence to the greatest extent possible.
- Actively solicit information that could further enhance the QEA.
- Remain available and approachable to respond to concerns.

The assessment process may be compromised if the assessor succumbs to indigenous hazards. Following are examples of special safety precautions that must be observed by industrial hygienists,

IN BRIEF

- **Workers in the power generation industry are exposed to many chemical, biological and physical health hazards.**
- **This article identifies examples of these hazards and discusses best practices for characterizing them.**
- **It also reviews the importance of implementing an effective continuous improvement cycle for controlling these health hazards.**

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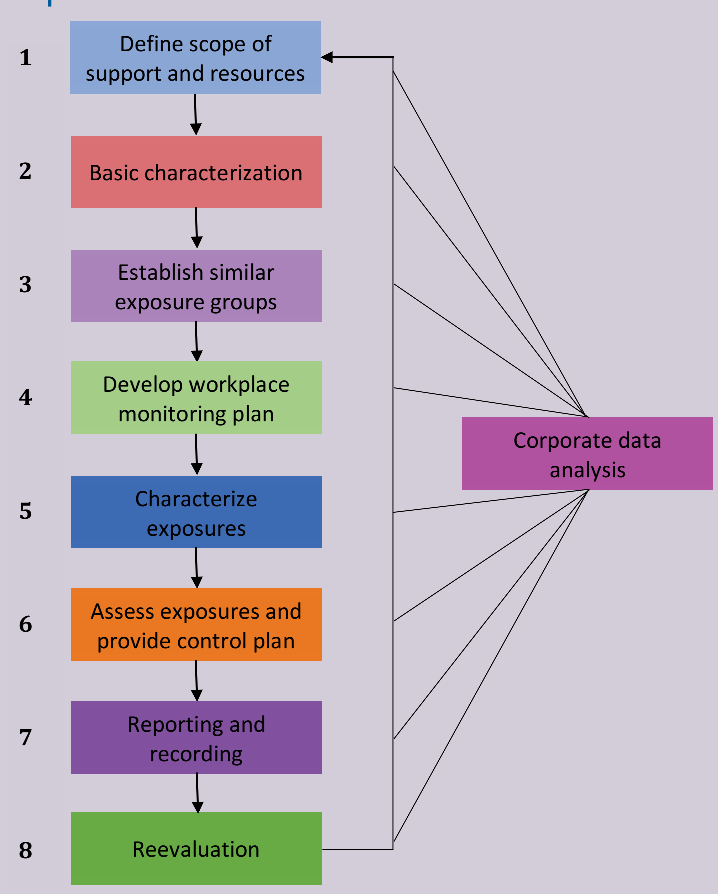
particularly when visiting unfamiliar power generation facilities:

•Participate in plant-specific visitor safety briefings that include a review of emergency procedures and special hazard areas (e.g., procedures for ammonia tank leaks, fires, confined space entries, work at heights, access to hydrogen areas).

•Wear proper arc-rated clothing when working in areas where there could be exposure to an arc flash of 2 cal/cm^2 or greater in incident energy.

•Properly wear NFPA 2112 clothing where flash fire hazards may exist. NFPA (2012) defines *flash fire* as "a fire that spreads by means of a flame front rapidly through a diffuse fuel such as a dust, gas or vapors of an ignitable liquid, without the production of damaging pressure." Combustible dust is present at coal-fired generation plants. According to OSHA (2010), NFPA 2112 is relevant in combustible dust environments and combustible dust is the number two cause of flash fires. Welding activities are also found at power generation plants. OSHA (2012) states, "if welders are exposed to flash fires or short-duration flame exposures, OSHA expects that employers would provide and ensure the use of FRC (flame-resistant clothing) to protect workers from these hazards."

FIGURE 1
Key Steps of a Qualitative Exposure Assessment



Note. *Adapted from Exposure Assessment Strategies, by U.S. Army Public Health Center, 2017.*

•Keep equipment not rated for Class 1 and 2 hazardous locations out of those hazardous areas. Class 1 hazardous locations are those where flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures. Class 2 hazardous locations are those where combustible dust (e.g., coal dust), rather than gases or liquids, may be present in varying hazardous concentrations (NFPA, 2017). Such equipment includes but is not limited to cell phones, cameras, testing and monitoring equipment, and sparking tools.

•Have a hard-hat-mounted light in case of a power outage accompanied by failure of backup power to avoid the many possible pitfalls present (e.g., conveyor belts, moving equipment parts, trip-and-fall hazards).

•Employ specialized fall protection equipment and training.

•Use appropriate respiratory protection in proximity to respiratory hazards.

•Wear appropriate eye protection when visually monitoring hot work activities or other eye hazards.

•Obey any warning signage and barriers (e.g., fall hazard areas, active lead or asbestos remediation areas, flash protection boundaries, scaffolding, radiofrequency radiation warning areas).

•Maintain situational awareness to be alert to potential crush hazards (e.g., moving machinery that might start remotely or at any time such as remote-controlled locomotives, conveyor belts, cranes, pumps, motors or heavy equipment).

Upon completion of the initial QEA, the resulting reports and databases, list problem areas ranked by risk level. These lists facilitate prioritized sampling and continuous improvement efforts, as well as effective resource allocation to minimize employee health risks to the greatest extent possible (e.g., training programs, medical surveillance programs, control measure implementation, gathering of additional data for program evaluation). Similar exposure groups are identified, and exposures are assessed and categorized as uncertain, acceptable or unacceptable. Sampling activities help with this categorization.

As occupational health hazards are identified in the QEA process, remain aware that the 2015 revisions to OSHA 29 CFR 1910.269(a)(3) and 1926.950(c) require the host employer to provide contractors with information on the known installation conditions, including any known safety-related environmental conditions. This has been interpreted to include information on occupational health hazards available through reasonable due diligence to host employers.

As chemical hazards are identified, also be aware that Subpart Z of both the OSHA General Industry Standard 29 CFR 1910 and the OSHA Construction Standard 29 CFR 1926 sets forth special requirements known as "substance-specific expanded standards" for the following toxic and hazardous substances that may be found at coal-powered generation plants: asbestos, cadmium, chromium (VI), inorganic arsenic, lead and respirable crystalline silica. (*Note*: An OSHA General Industry expanded standard for beryllium, 29 CFR 1910.1024, took effect on May 20, 2017. This standard requires employers to comply with most elements of the rule starting March 12, 2018. The rule is in litigation at this time. Among several points of concern for coal-powered generation plants in this standard as presently written are dermal contact provisions and beryllium work area provisions. It is recommended that the status of this standard be monitored closely by those operating coal-powered generation plants.)

Once hazards are identified, the hierarchy of controls must be applied to bring worker exposure within acceptable limits, most typically in the U.S., OSHA permissible exposure limits. Many U.S. organizations choose to replace OSHA permissible exposure limits (PELs) with the more conservative ACGIH threshold limit values (TLVs) or other occupational exposure limits (OELs) (e.g., military, NIOSH). Where no other OEL is available, some employers choose to use OELs from foreign countries, manufacturers' recommended exposure limits and control banding.

In contemplating OELs, note that NIOSH states that there is no safe exposure limit for carcinogens, and exposure should be limited to the greatest extent possible regardless of established OELs. Caution should be used in reading SDS. Sometimes hazardous by-products may be generated through normal wear and maintenance activities and the SDS may not make this clear.

For illustrative purposes, case study QEA information is presented next. This information is not exhaustive of occupational health hazards found in the power generation industry. Exposures may vary vastly between different organizations or even between different sites or operations within a single organization, and all sites must take appropriate measures to identify, characterize and control their own site hazards.

Photos 1 and 2: Examples of peaker units. Peaking power plants, also known as *peakers*, are power plants that generally run only when there is a high (peak) demand for electricity.

Health Hazards at Peakers

Peaking power plants, also known as *peakers*, are power plants that generally run only when there is a high (peak) demand for electricity (Photos 1 and 2). Because they supply power only occasionally, the supply commands a much higher price per kilowatt-hour than base load power. Peakers are typically fueled by natural gas, diesel fuel or both. Gas turbine control technicians, control mechanics and plant operators operate gas turbines, perform preventive maintenance and monitor units.

Repetitive Tasks

Monitoring numerous screens for extended periods may result in eye strain, particularly if the screens are small. Mental stress is another pronounced hazard related to operation of peaker sites. Technicians spend prolonged periods performing repetitive and perhaps monotonous preventive maintenance and testing activities, but actually run the units only sporadically during peak periods. But when their service is required, there is extreme pressure that they run flawlessly. If units do not operate properly and immediately when called upon, technicians must make a go/no-go decision with significant implications to people, property and finances. They may need to safely make a repair quickly under great pressure. If a unit does not start, an outage may be declared, which has large financial implications. This may jeopardize worker safety and equipment worth millions of dollars that could be subject to damage.

Noise & Chemical Exposures

Preventive maintenance activities performed in turbine compartments with turbines and fans running expose employees to noise and, in some cases, diesel exhaust for limited periods, particularly if there is a compartment leak or temperature inversion holding the exhaust close to the ground occupied by workers. Diesel exhaust is an IARC Group 1 carcinogen and, regardless of established OELs, it is prudent to heed NIOSH's recognition that no safe level of exposure to a carcinogen exists. Therefore, reducing worker exposure to chemical carcinogens as much as possible through elimination or substitution and engineering controls is the primary way to prevent occupational cancer.

Asbestos

Asbestos may be encountered by workers removing gaskets that contain asbestos, and asbestos insulation may be found on some older equipment on site.

Soldering with tin/lead 20/80 flux core solder in a maintenance shop without adequate ventilation could expose workers to colophony, a sensitizer that is an airborne by-product with an assigned ACGIH TLV. In this process, surprisingly, lead is not heated to temperatures high enough to pose a significant inhalation hazard; however, uncleaned accumulations over time on work surfaces can pose an ingestion hazard.

Bacteria

Raccoons and other animals can move in under floor crawl spaces and get into panels beneath a facility's equipment. This can expose workers to decaying animals, urine and feces and, thereby, a wide variety of diseases and parasites such as *Escherichia coli*, *Baylisascaris*, *Giardia*, *Salmonella*, *Campylobacter*, *Toxoplasma gondii*, roundworms and hook worms. Mice can also expose workers to hantavirus.

Ergonomic Stressors

Handling battery trays that may weigh more than 160 lb, moving drums of oils and coolants, and moving compressed gas bottles containing nitrogen and carbon dioxide can expose workers to ergonomic stressors unless appropriate controls are used.

Mercury, Radiation, Toxic Fumes

If not handled properly, broken mercury switches, controls and relays, and mercury thermometers in laboratories may expose workers to mercury.

Even workers who do not perform welding, while performing contract monitor or fire watch duties, may be exposed to ultraviolet (UV) radiation hazards that affect the eyes and body, as well as toxic welding fumes produced by contractors. These toxic fumes may contain the metals aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, silver, tin, titanium, vanadium and zinc. They may also contain the process-related air contaminants nitric oxide, nitrogen dioxide, carbon monoxide, ozone, phosgene, hydrogen fluoride, asbestos, carbon dioxide and other hazardous constituents.

Cryogenic, Exhaust & Fire Hazards

While handling bulk carbon dioxide deliveries for fire extinguishing systems, workers must take appropriate precautions due to the cryogenic hazards present.

Natural gas fuel systems and hydrogen cooling systems require controls to prevent explosion and fire risks. Workers must maintain awareness for system leaks, and receive special annual training on safe system management and how to work safely in the presence of these gases.

Health Hazards at Coal-Fired Power Plants

Myriad occupational health hazards are associated with coal-fired power plants, making hazard control efforts in these locations challenging. A select few are presented here.

Fire & Explosion

Class I hazardous areas (e.g., methane, hydrogen) may be found at coal-fired power plants. Coal contains trapped methane. Lighter-than-air methane may migrate out of the coal in unventilated silos or similar spaces and accumulate toward the top of the silo, creating a fire and explosion hazard.

Hydrogen is used to cool hydrogen-cooled turbo-generators. Because of the high thermal conductivity and other favorable properties of hydrogen gas, this is the most common generator cooling material. Hydrogen is lighter than air; leaks in hydrogen systems tend to result in hydrogen accumulating near the ceiling, creating a fire and explosion hazard.

Combustible Dust

Class II areas may also be found at coal-fired power plants; coal operations release combustible coal dust. Among the numerous safety requirements related to combustible dusts, housekeeping is important. Housekeeping should ensure that accumulations do not exceed 1/32-in. over 5% of the floor area, in ductwork and pipes, on I-beams and tops of cabinets, and on other surfaces. Personnel should also check for hidden accumulations above false ceilings.

Perhaps the most obvious and ubiquitous occupational health hazard associated with coal-fired plants is exposure to toxic constituents of coal dust, fly ash and bottom ash. While the actual composition of coal dust varies significantly depending on the source of the coal, coal typically contains the following hazardous constituents: crystalline silica (an IARC Group 1 carcinogen) and calcium oxide, together with trace amounts of any of a variety of metals, including antimony, arsenic, beryllium, cadmium, cobalt, chromium, lead, mercury, manganese, nickel and selenium. Combustion of that

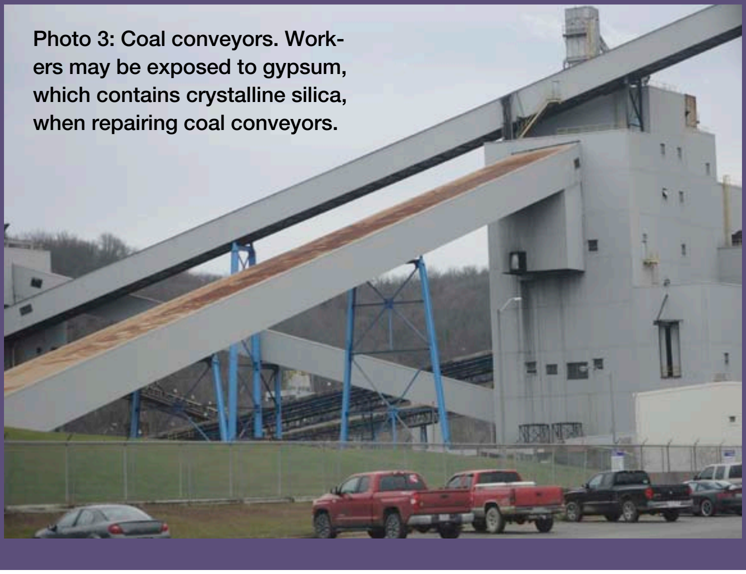


Photo 3: Coal conveyors. Workers may be exposed to gypsum, which contains crystalline silica, when repairing coal conveyors.

same coal in power generation yields fly ash and bottom ash. As the bulk of the coal burns off, the remaining ash concentrates the trace elements, increasing their concentrations.

Crystalline Silica, Coal Dust

Workers may be exposed to coal dust and fly or bottom ash as a result of myriad activities. It is important to identify and assess these various exposures to the inhalation and ingestion hazards.

Workers may be exposed to crystalline silica, an IARC Class 1 carcinogen, through various routes. Coal-fired power plants that add cement kiln dust to the coal before burning as an environmental control need to be aware that while dust compositions and processes can vary widely, the dust may contain appreciable amounts of crystalline silica to which workers can be exposed.

One study conducted by the author for a facility using cement kiln dust for which the SDS indicated up to 10% crystalline silica content, found the exposure potential for the cement kiln dust management contractor workers and coal stacker tower cab operators above OELs for crystalline silica in the absence of adequate controls. Exposure may vary widely with the addition of dust suppressants, wet or dry weather conditions, dust addition process, condition of control equipment and PPE. Coal dust itself contains varying but appreciable amounts of crystalline silica; and a variety of workers may be exposed to this contaminant.

Controls may vary widely from one plant to another, but ongoing good housekeeping and properly performed dust suppression activities, are key to minimizing exposure. Coal dust may be found in process areas, but may also find its way into worker food preparation and break areas through poor cleaning and hygiene, and into plant ductwork where it may be transported throughout the plant. It could also pose a hazard for HVAC contractors cleaning ductwork.

Another potential source of exposure is abrasive blast media comprised of crystalline silica or coal slag, which contains beryllium. Exposure may occur when transferring media to abrasive blast cabinets, stored in uncovered buckets, leaked material due to poor housekeeping, and from improper cleaning such as dry sweeping. Gypsum contains crystalline silica and calcium sulfate. Workers may be exposed to gypsum when making repairs to conveyors while gypsum is being run, and when repairing casing leaks in the flue gas desulfurization (FGD) systems (Photo 3). Exposure may also result from spread contamination throughout facility, roads and vehicle interiors, with fugitive dusts varying in airborne concentration.

Asbestos

Asbestos exposure is possible in various ways. Vehicle maintenance shop personnel can be exposed to asbestos, as in the U.S. many brakes and clutches are still manufactured with asbestos. For shops that perform more than five brake/clutch jobs per month, OSHA specifies required control measures. Asbestos was also historically used in hood liners and other automotive parts that were required to withstand heat damage.

While servicing transformers and during inspection, racking or cleaning of ITE breakers with asbestos-containing arc chutes, plant maintenance workers may be exposed to asbestos dust. Maintenance workers modifying asbestos lab countertops may also encounter asbestos dust. Labeling these countertops with a warning could prevent maintenance personnel from unknowingly disturbing the material.

Asbestos exposure may occur during breaker verification, while working around asbestos plates and cables, and during monthly servicing of coal handling motor drum brakes and clutches.

Welders may be exposed to asbestos in several ways. For half a century starting in the 1930s, asbestos-coated welding rods were common. These rods contained high levels of amphibole asbestos, most often the crocidolite or blue variety, which is known for its ability to resist electrical current (Asbestos.net, 2017b). All old stocks of welding rods should be examined and asbestos rods should be removed for proper disposal.

Likewise, older welding blankets, gloves and aprons were made from asbestos cloth or were lined with asbestos. Exposure to high temperature open flame, or rips in the fabric or at the seams would release millions of microscopic fibers into the air (Asbestos.net, 2017a). Any of these products in use should also be removed for proper disposal. Flange gaskets scraped or ground off by maintenance workers may contain asbestos as well.

Extreme Heat

Power generation creates a lot of heat. In older plants, insulators, pipefitters, electricians, welders and other laborers may still often work in close quarters with or disturb asbestos located on or in walls, wires, pipes, cable trays, boilers, generators and other machinery (Asbestos.com, 2017).

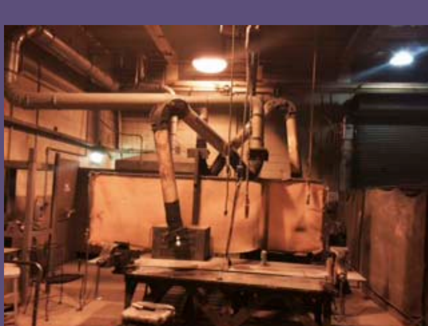
Ozone

Ozone is formed from dioxygen by the action of UV light and electrical discharges, both of which may be found in abundance in power generation plants. Welding activities generate ozone, as do large motors that use brushes, such as those used by elevators or hydraulic pumps, generators and exciters. Turner, Jerrett, Pope, et al. (2016, as cited in Smith, 2016), highlight ozone risks with a detailed study that links ozone exposure with an increased risk of fatal respiratory and cardiovascular diseases. Every additional 10 ppb in long-term ozone exposure increases the risk of dying from lung disease by 12%.

Burning coal creates nitrogen oxides (NOx) which cause ground level ozone. Ammonia may be used to eliminate NOx emissions through the selective catalytic reduction process. Such a process injects ammonia gas into boiler flue gas and passes it through a catalyst where the ammonia and oxide gas react to form into nitrogen and water vapor. Maintenance workers can be exposed to ammonia through leaks and all personnel may be impacted by emergency large-scale releases from bulk ammonia tanks.

Chemical Exposure

Flue gas usually contains carbon dioxide, particulate matter, carbon monoxide, nitrogen oxides, sulfur oxides and mercury. While repairing FGD system leaks, workers may be exposed to these contaminants. The sulfur dioxide also reacts with any moisture present, including moisture in the lungs, to create sulfuric acid. Some typical sources of these sulfur dioxide leaks may include stuck bypass dampers and leaking seals around ID fans, booster fans and dampers. Employees may also be exposed to flue gas when troubleshooting and repairing duct leaks, failed probes and limit switches on the FGD system.



Photos 4 and 5: Welding ventilation (Photo 4, above) is essential to combat possible chemical exposure hazards found in many weld shops (Photo 5, left).

Lead exposure may result from maintaining plumbing in older plants, particularly when sweating old lead pipes, an activity that involves cutting lead pipe, removing old lead solder by heating lead pipe and soldering with a torch. Lead exposure may also result from contact with used oil from terne-plated oil filters used in heavy-duty applications.

Most automobile oil filters are non-terne-plated while industrial filters, heavy equipment filters and other types may be terne plated. Terne is an alloy coating historically made of lead and tin and used to cover steel, in the ratio of 20% tin and 80% lead. Currently, lead has been replaced with the metal zinc and is used in the ratio of 50% tin and 50% zinc. However, some older filters may remain in service. Usually the manufacturer, parts store or other sources have information if the filters are terne or non-terne plated.

Lead exposure may also result from welding operations on brass, bronze and other materials; from exposure to trace amounts of lead in coal dust, fly ash and bottom ash; and from lead coatings and paints (Photos 4 and 5).

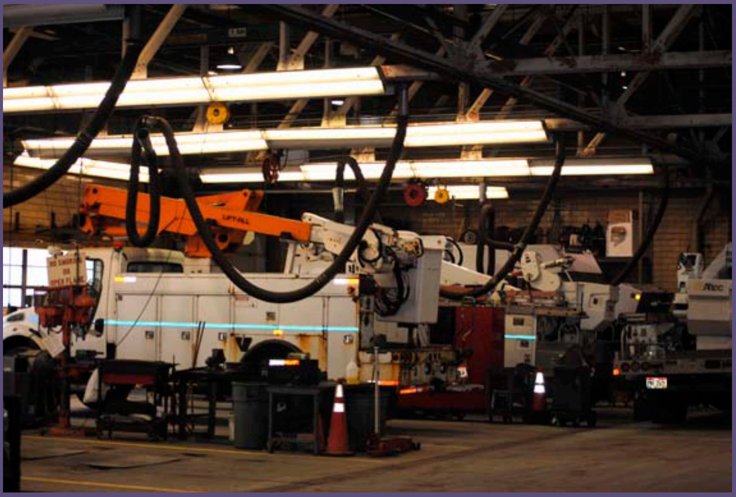
Most large steam turbine-generators utilize an electrohydraulic control (EHC) system high-pressure fluid to position their governing and tripping valves. On most modern large steam turbines the main turbine bearing oil is not used for EHC control but a separate specialized fire-resistant EHC fluid is used for both the turbine valve actuators and the turbine trip system (Barry Sibul Co., 2016). During activities related to the servicing of the EHC system, such as checking and replacing O-rings of Victaulic fittings, cleaning and servicing system, workers may be exposed to mist of triphenyl phosphate found in some fire-resistant EHC fluids. Triphenyl phosphate may be absorbed through the skin, has an established TLV and is a cholinesterase inhibitor.

Lab and maintenance workers may be exposed to mercury. Mercury (II) iodide is used in the preparation of Nessler's reagent, which is used to detect ammonia leaks. Mercuric thiocyanate is used in the determination of chloride ions in water by UV-visible spectroscopy. One use of this test is the analysis of antifreeze from heat exchangers for chloride ion. Interestingly, when mercuric thiocyanate and chloride are mixed they form a complex that absorbs light at 254 nm. Some pH buffer solutions contain mercuric chloride. In addition, certain laboratory applications still require the use of mercury thermometers, which can break and release elemental mercury. Old floats and switches can also contain elemental mercury; when damaged, these devices may release mercury, which is volatile and may be inhaled.

Lab workers may also be exposed to organic arsenic when phenylarsine oxide solutions are made up and transferred to ampometric titrators to test for total chlorine used to get rid of zebra mussels. Arsenic is also present in trace amounts in coal dust, fly ash and bottom ash. Boiler reheats and superheats, and baghouses are two areas prone to concentrated arsenic levels.

Fiberglass is damaging to the lungs if inhaled and is found throughout the plant. Removal of inspection covers and inspection of boiler feed pump turbines exposes workers to fiberglass insulation dusts. Workers may also be exposed to fiberglass during removal, replacement, installation and repair of fiberglass insulation, particularly during fiberglass sanding activities. Repair activities may also expose workers to adhesive resins and hardeners, some of which may contain harmful components such as styrene, bisphenol A (which has no U.S. occupational exposure limit but has been assigned a German MAK value) and imidazole (which has no U.S. occupational exposure limit but has a manufacturer recommended limit and may be absorbed through the skin).

Occasionally, soot must be removed from soot blowers. Soot is a complex mixture that includes carbon, sulfuric acid, and mutagenic and carcinogenic polycyclic aromatic hydrocarbons; applicable PELs include the OSHA PEL for coal tar pitch volatiles. Exposure to soot may also result from maintenance of continuous emissions monitoring system monitors and probes, particularly on inlet side before flue gas gets scrubbed, with units on line and creates a potential for leakage. Flue gas contains sulfuric acid, sulfur dioxide, carbon dioxide, carbon monoxide and nitrogen dioxide. Workers occasionally exposed to burning coal pile combustion products are also exposed to these same components. Workers may also be exposed to disturbed soot particles when working on the grating of soot blowers to get to stream valves.



Photos 6 and 7: If care is not taken to protect workers, they may be exposed to chronic exhaust in vehicle maintenance shops.

Radiation

Workers may be exposed to refractory ceramic fiber (RCF), a synthetic vitreous fiber that has an assigned OSHA PEL and ACGIH TLV, while preparing wet refractory for boiler installation from a dry RCF mix; and while removing refractory material. RCF may induce eye and skin irritation and adverse respiratory health effects, including lung cancer.

Workers may be exposed to nonionizing radiofrequency (RF) radiation. It is not uncommon to find RF antennas mounted on rooftops at power generation plants. U.S. Federal Communications Commission requires that hazard assessments be performed for such antennas and appropriate control measures taken where indicated by these assessments to protect workers.

RF radiation is also a by-product of the power generation process. It is prudent to mount signage at the plant entrance to warn those with implanted medical devices of its presence because of the potential for RF to interfere with the proper performance of these important devices.

Many coal-fired power generation plants contain one or more sources of ionizing radiation and these sources are frequently overlooked.

Many welders use 2% thoriated tungsten electrodes, which, when ground to shape the tip to a point, release dusts containing radioactive thorium oxide (emits mainly alpha particles, but occasionally some beta and gamma radiation). With poor housekeeping and absent local exhaust ventilation, these radioactive dusts may accumulate on surfaces where they may become entrained in the air and subsequently be breathed in by workers.

While worker training and housekeeping are key protective measures, the best protection is to replace the 2% thoriated tungsten electrodes with safer alternatives (e.g., ceriated or lanthanated tungstens for work with a DC current, and zirconiated tungsten for AC current welding).

Workers near magnetic separators (devices that detect foreign objects) may be exposed to ionizing radiation from detectors in the absence of proper energy control procedures.

In X-ray fluorescence spectrometry, high-energy primary X-ray photons are emitted from a source (X-ray tube) and strike the sample in the performance of nondestructive elemental analysis. Plants using portable handheld X-ray fluorescence spectrometers must take measures to prevent improper use (e.g., pointing it at a person energized or deenergized) or damage to the unit that could result in ionizing radiation exposure.

Combustor refractory emits ionizing radiation. The bricks are usually composed of a combination of clay and minerals, with silica, alumina or kaolin in the mix. The ore that is mined for use as refractory brick (i.e., bauxite) is commonly found in the presence of naturally occurring radioactive elements, such as uranium and thorium. These elements often end up in the finished brick.

When bituminous coal is burned in boilers to create steam for power generation, the volume of coal is reduced by more than 85%; as a result, tiny amounts of naturally radioactive uranium and thorium are concentrated at up to 10 times their original levels (Hvistendahl, 2007). These residuals are called technologically enhanced naturally occurring radioactive materials (TENORM), and they end up in fly ash, bottom ash and boiler slag. TENORM are in contact with the RCF and may impart radioactivity to the RCF.

During removal of refractory from combustors, the author has measured as high as 60 µRem/hr alpha radiation (with no detectable level of beta radiation identified) emanating from the refractory. This radiation level poses no significant hazard to worker health. Yet, problems may arise during the disposal phase if a lack of awareness exists of applicable local regulations governing disposal of radioactive materials at these levels; for example, the Pennsylvania Department of Environmental Protection requires Bureau of Radiation Protection prior approval for disposal in that state of TENORM exceeding a surface dose rate > 50 µRem/hr.

Chlorinated solvents may abound, including 1,1,1-trichloroethane, methylene chloride, trans-1,2-dichloroethylene and trichloroethylene (e.g., cutting fluids, contact cleaners, degreasers, insecticides, flux removers, paint stripper, epoxy remover). Chlorinated solvents may pose pronounced health hazards in and of themselves, and when converted by UV radiation from welding/cutting/grinding processes to potentially deadly phosgene gas. It may be prudent to seek safer replacements for chlorinated solvents and to teach workers to keep all chlorinated solvents out of areas where these activities are carried out.

Photo 8: Cooling towers may harbor Legionella; activities to maintain cooling tower pumps, inspect and service equipment, collect samples, clean screens or add chemicals to circulating water systems may expose workers.

Carcinogens, Toxins & Bacteria

Opportunities for worker exposure to carcinogenic diesel exhaust abound (e.g., fossil-fuel burning portable sump pumps, heaters, generators, welders, trucks, heavy equipment, forklifts, aerial lifts, telehandlers). If care is not taken, workers may be exposed to chronic exhaust (Photos 6 and 7, p. 55). Exhaust sources must not be located near building air intakes.

Asphalt-based adhesives contain toluene diisocyanate and methylene bisphenol isocyanate. Isocyantes can sensitize workers, making them subject to severe asthma attacks. There is evidence that both respiratory and dermal exposures can lead to sensitization.

Water resources may pose unexpected, unique hazards. For example, according to some sources, the Ohio River has been recognized as the most polluted body of water in the U.S. for 7 consecutive years (Shack, 2015). Water from the river often may be used for many purposes, including dust suppression. When workers fill trucks from hydrants that draw river water, they may become doused with the water during this process. The trucks then spray the water on the road.

Workers may come into contact with contaminated water through many other processes as well. Analysis has shown that the water is contaminated with PCBs, dioxin, diesel fuel and other contaminants. In 2015, the poisonous blue-green algae microcystis, a source of increasing concern in the U.S., plagued 636 miles of the river.

Cooling towers may harbor Legionella; activities to maintain cooling tower pumps, inspect and service equipment, collect samples, clean screens or add chemicals to circulating water systems may expose workers (Photo 8). Wearing appropriate PPE is key to prevent exposure.

Paint removal may expose workers to lead and PCBs. Lead, a common component in paints for many years, was used as a pigment and as an additive to speed drying, increase durability, retain a fresh appearance and resist moisture that causes corrosion. Paint from surfaces coated prior to 1978 should be assumed to contain lead unless laboratory analysis proves otherwise.

Historical coating systems that may contain intentionally added PCBs include corrosion-resistant epoxy resins used on metal surfaces, film casting solutions for electrical coatings, and some varnish, lacquers and waterproofing coatings (O'Malley, 2014). PCBs might still be present in paint as unintended by-products of the production of two organic pigments: phthalocyanines, which impart a deep blue or green color, and azo pigments, used to color some paints yellow, red or orange. Hu

(2009) reports that sampling and analysis of several common name-brand paints revealed the presence of PCB-11 and PCB-209 in amounts ranging from 2 to 200 ppb.

Those with groundskeeping duties may be exposed to Glyphosate (N-(phosphonomethyl)glycine) found in Monsanto's Roundup weed killer. Growing concern and controversy surrounds this substance amidst new assertions as to the toxicity of the compound. In 2015, International Agency for Research on Cancer (IARC, 2016a) declared Glyphosate a Group 2A carcinogen, finding it "probably carcinogenic to humans." Sri Lanka, alarmed by suspected links to human kidney disease, has banned it. Brazil is considering a similar move, while Mexico and the Netherlands have imposed new restrictions, and Canada has initiated a process to consider new rules (Grossman, 2016). However, Glyphosate manufacturer Monsanto, EPA and others have disagreed with the IARC findings. IARC (2016b) reports World Health Organization's response in its Q&A on Glyphosate.

Micarta industrial laminate, a thermostatic composite consisting of a cured phenol-formaldehyde on a cotton fabric substrate, is a high strength electrical insulation used in power generating and distribution equipment. Machining, grinding and making repairs to Micarta (e.g., repairs of bottom ash piping) may expose workers to phenol and formaldehyde.

Noise & Ergonomic Hazards

Many sites maintain their own firefighting teams. Firefighting efforts at power plants may expose workers to hundreds of toxic compounds (Ellis, 2004) and pronounced ergonomic hazards.

Noise hazards abound at power plants. Three of the most notable are sandblasting operations, thermal spray operations and boiler deslagging operations using shotgun shells or explosives.

Conclusion

Occupational health hazards in fossil fuel power generation operations are numerous and diverse. What does not vary between facilities, however, is the need to effectively and continuously identify, characterize and control those hazards to protect the health of all workers and maintain a sustainable operation. **PS**

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